The Power of Wind

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National Wind Technology Center

What is Wind Power?

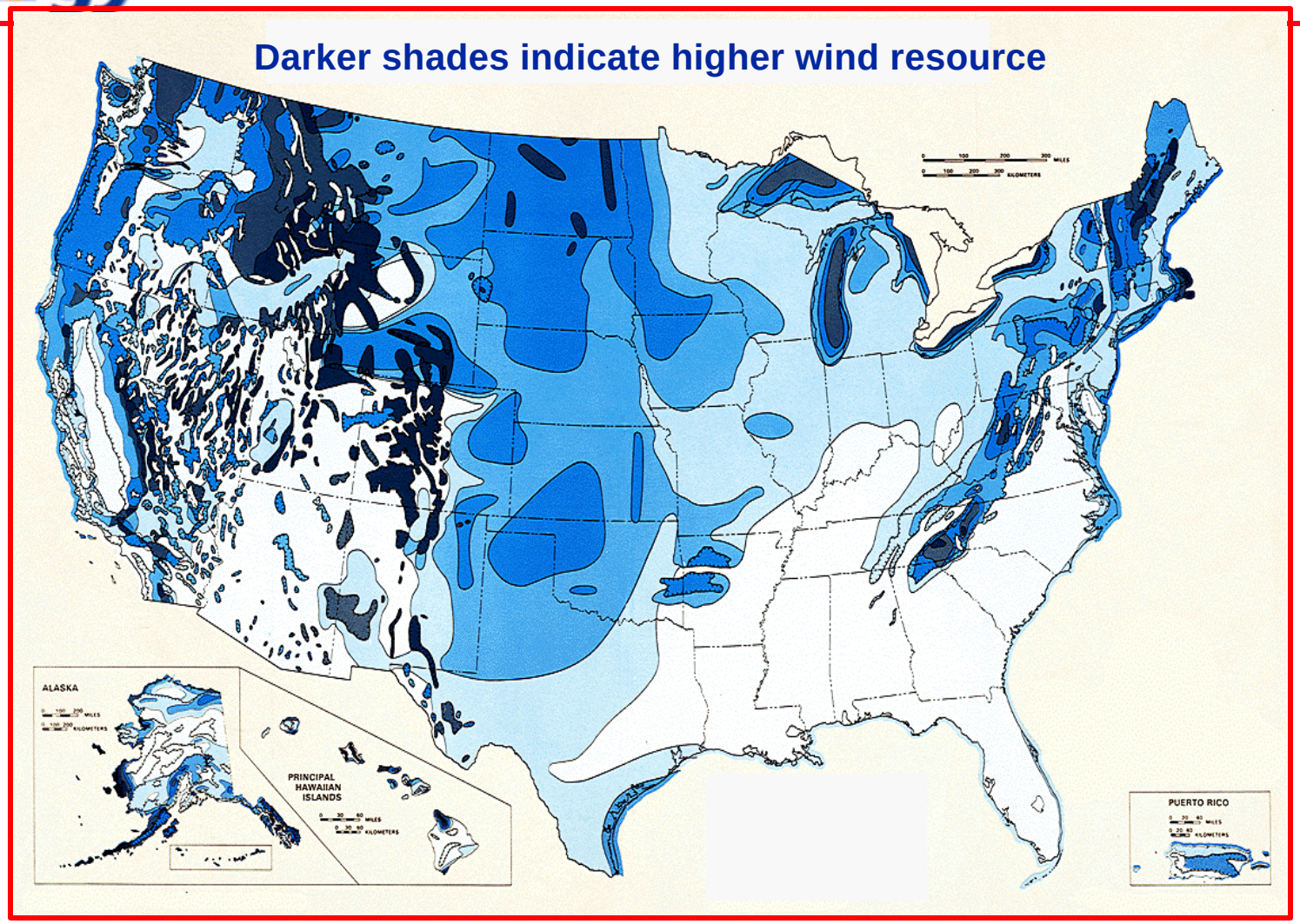
- Not a new concept
- Many advances have brought efficiency up and costs down

What is wind power?

$$P/A = \frac{1}{2} r V^3$$

- Wind Energy Conversion Device
  - Literally converts energy in wind to electrical or mechanical energy
  - Power in the wind increase with the cube of the wind speed

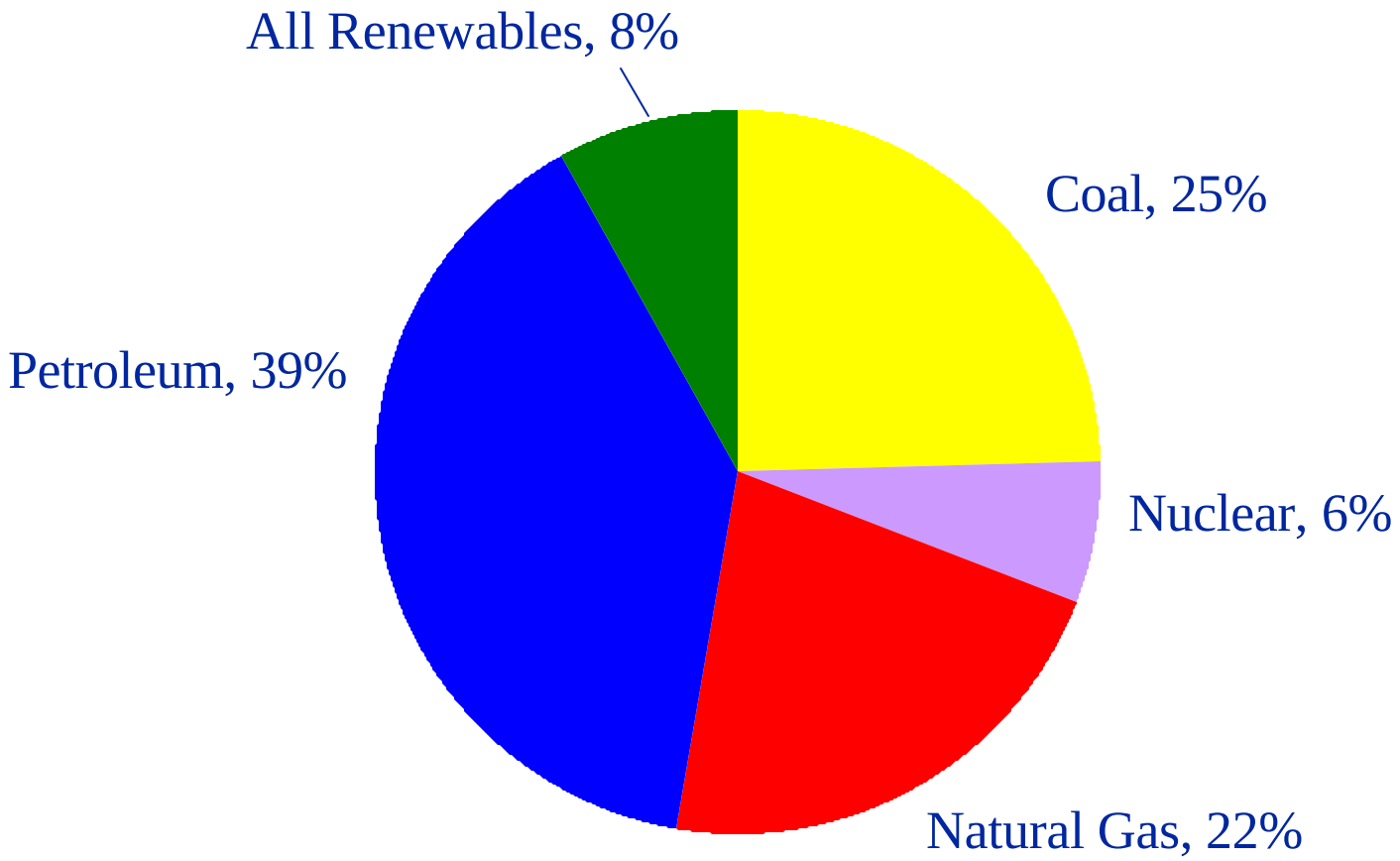
Average Annual Wind Resource



Recent Electricity Market Volatility

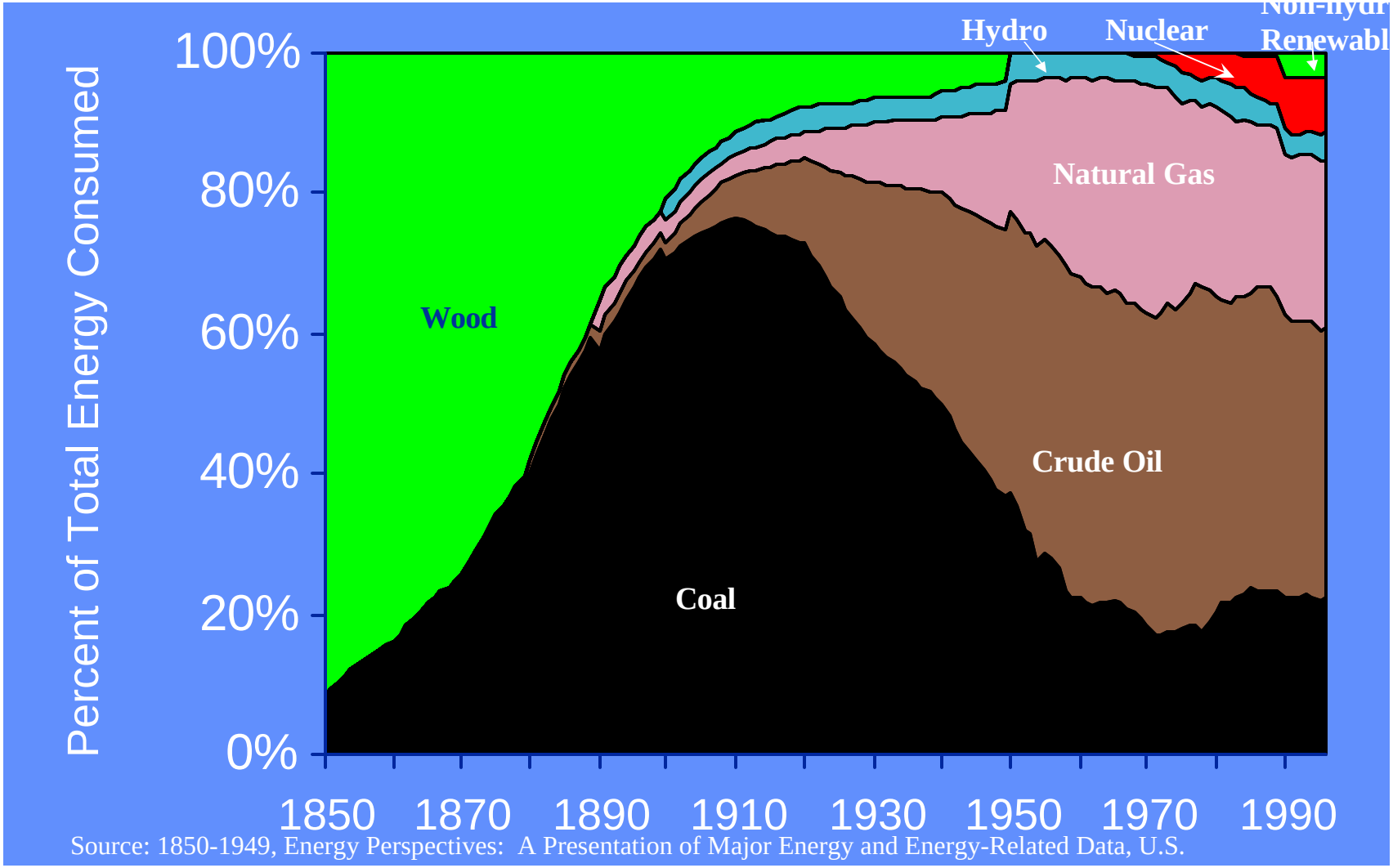
- Supply shortages in California and Northwest
- Price spikes
- Rolling blackouts
- Similar problems forecast for New York

Worldwide Energy Consumption
By Source - 1997



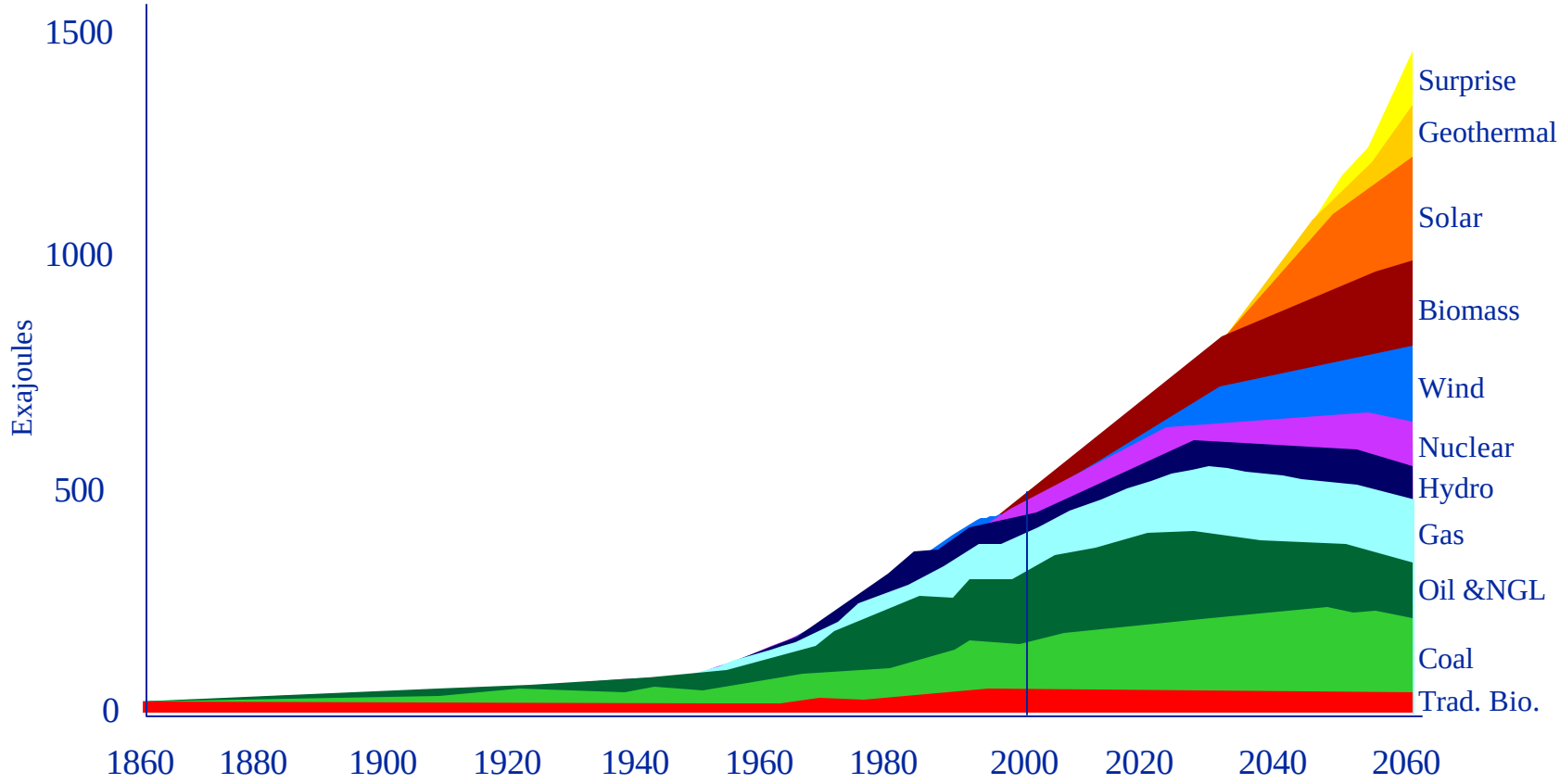
Source: Energy Information Administration, *International Energy Outlook 2000*, Table A2

U.S. Energy Production by Source
1850-1996

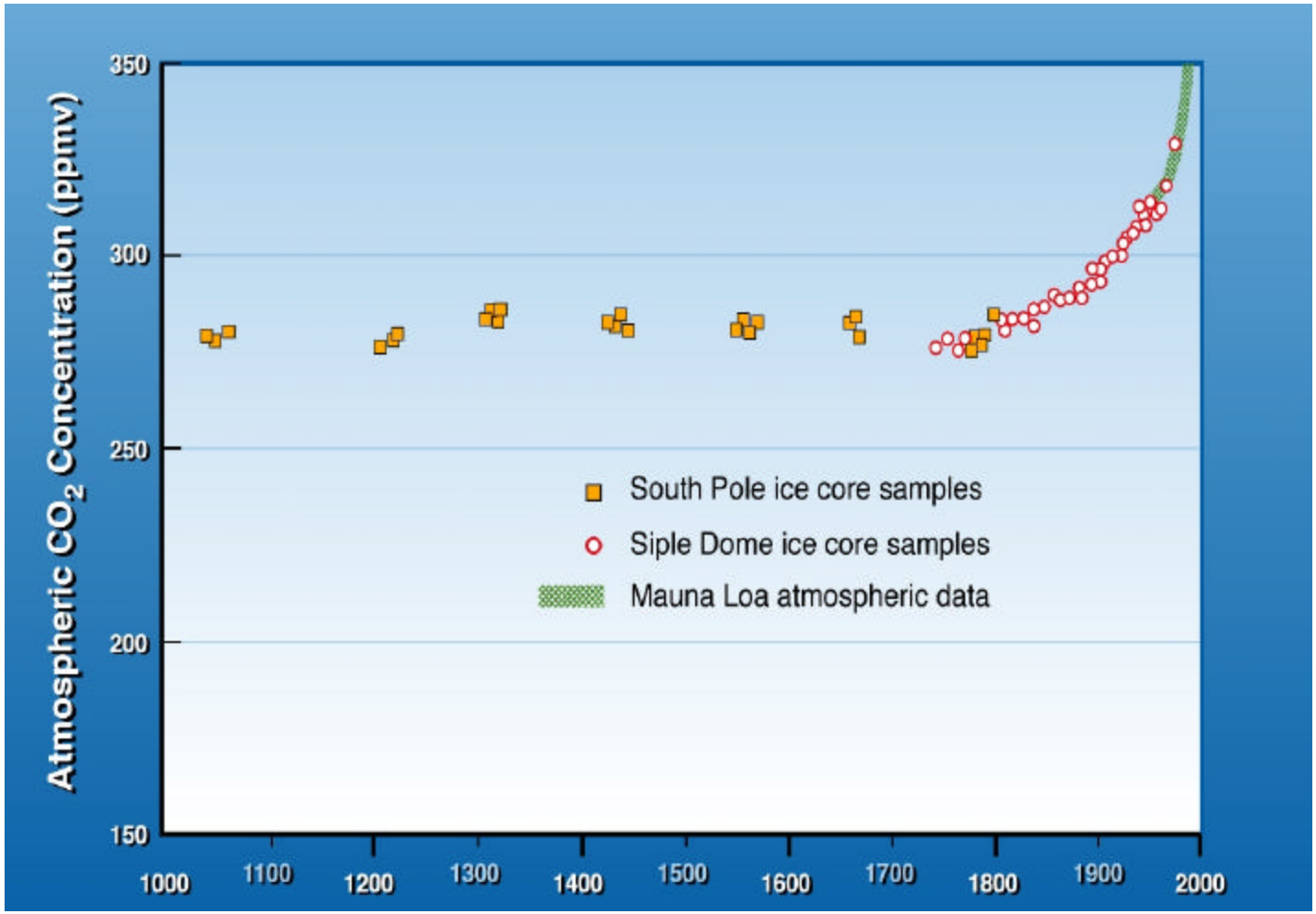


Source: 1850-1949, Energy Perspectives: A Presentation of Major Energy and Energy-Related Data, U.S.

Shell Sustained Growth Scenario



Atmospheric Concentration of CO_2

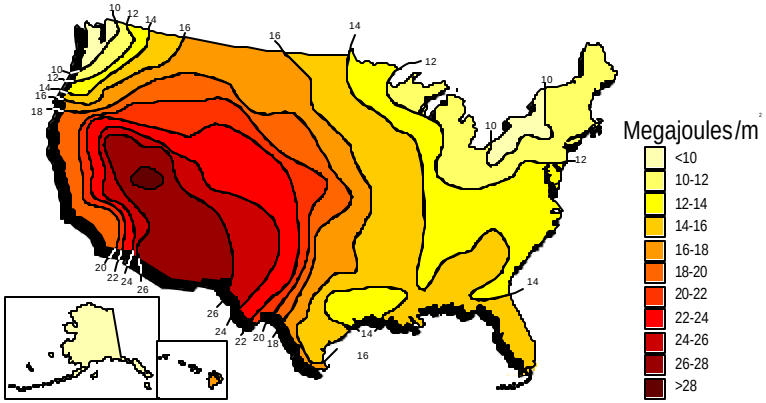


Renewable Energy Pathways

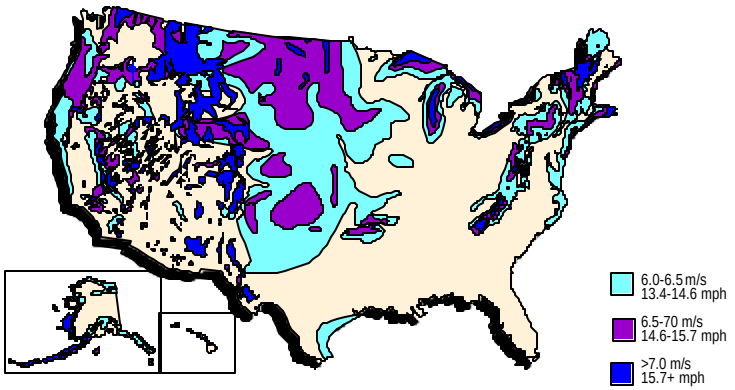
- Wind Energy
- Solar Photovoltaics
- Solar Thermal Electric
- Solar Buildings
- Biomass Electric
- Biomass Transportation Fuels
- Geothermal Energy
- Hydropower

U.S. Renewable Energy Resources

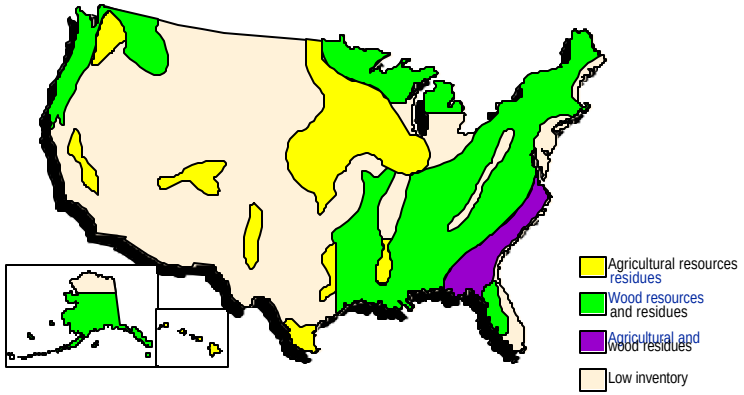
Solar



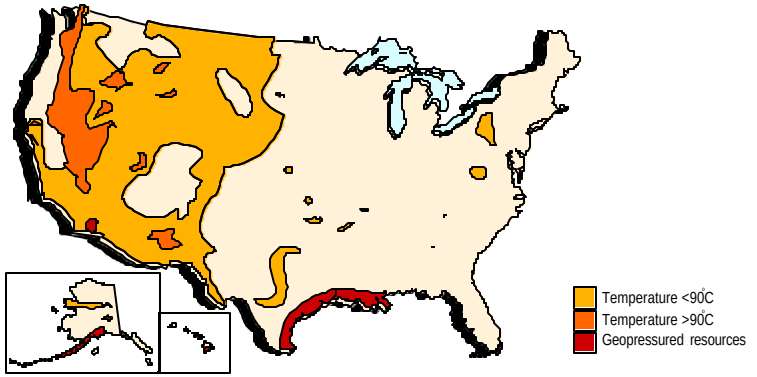
Wind



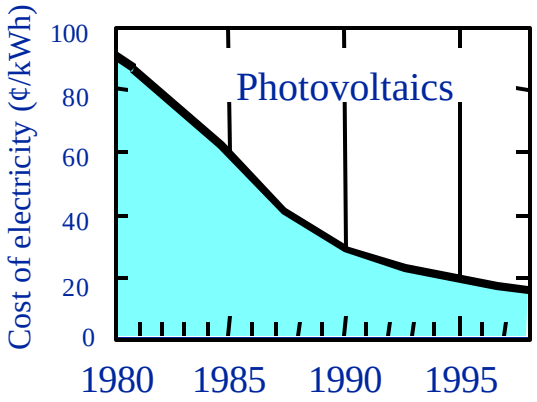
Biomass

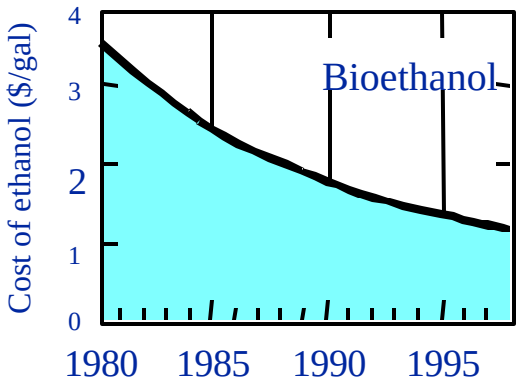


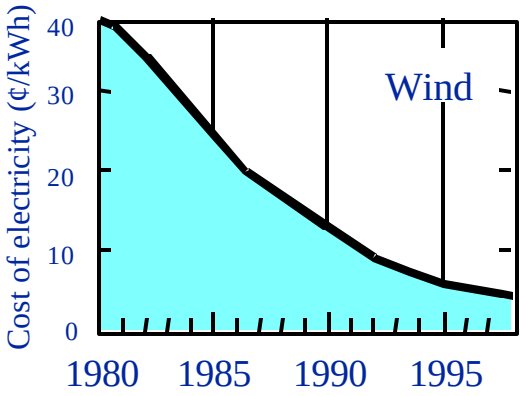
Geothermal

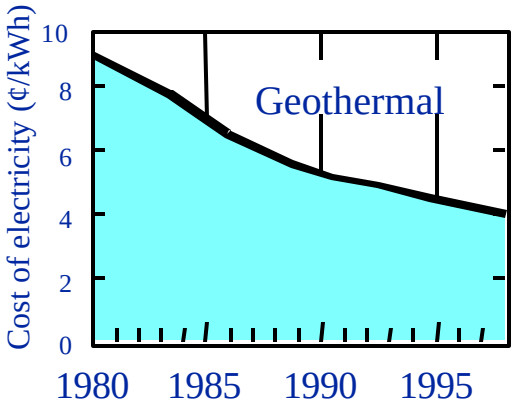


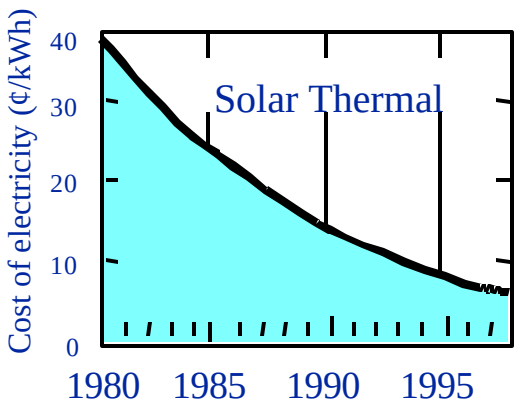
Renewable Energy Cost Trends

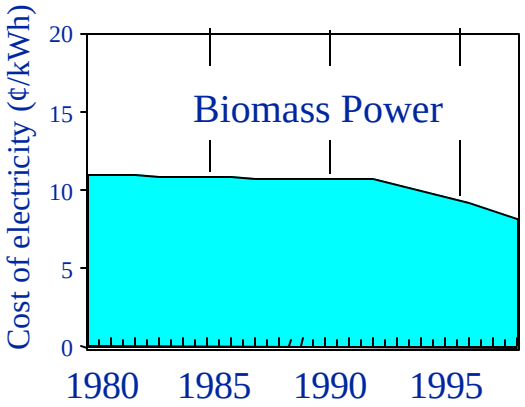






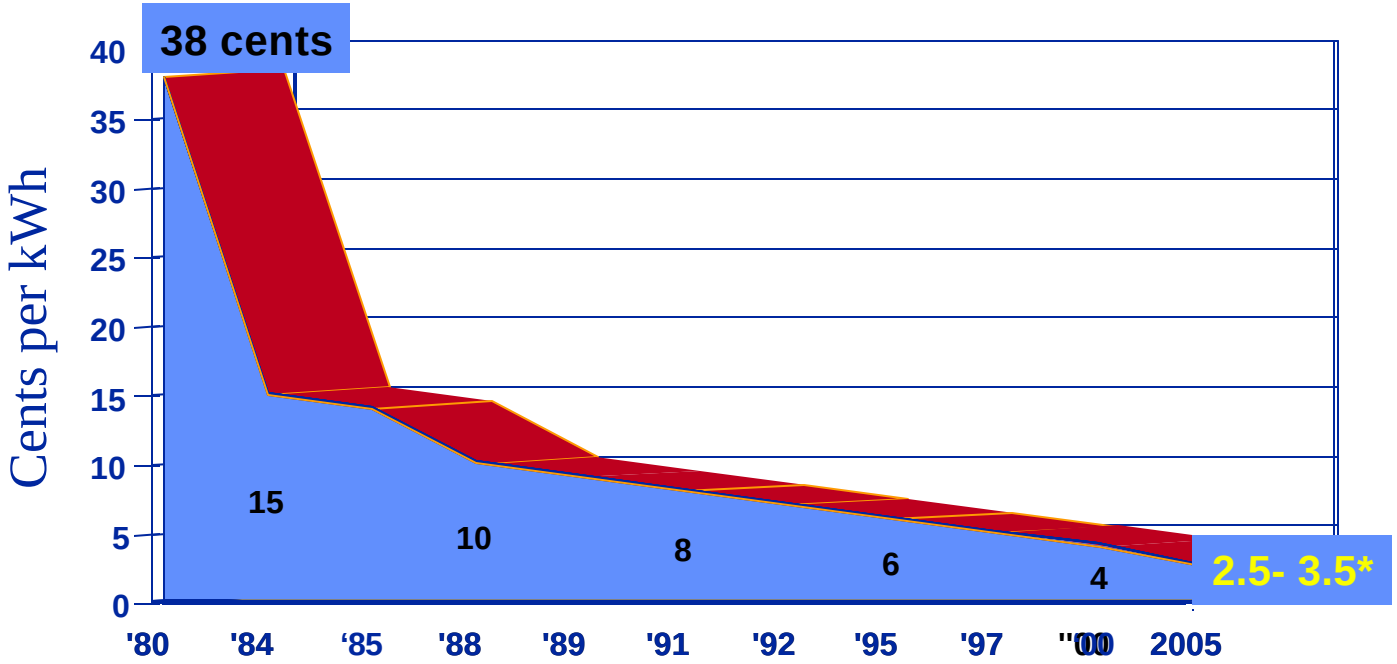






Wind Energy Cost

Cost of Wind-Generated Electricity 1980 to 2005, Levelized cents/kWh



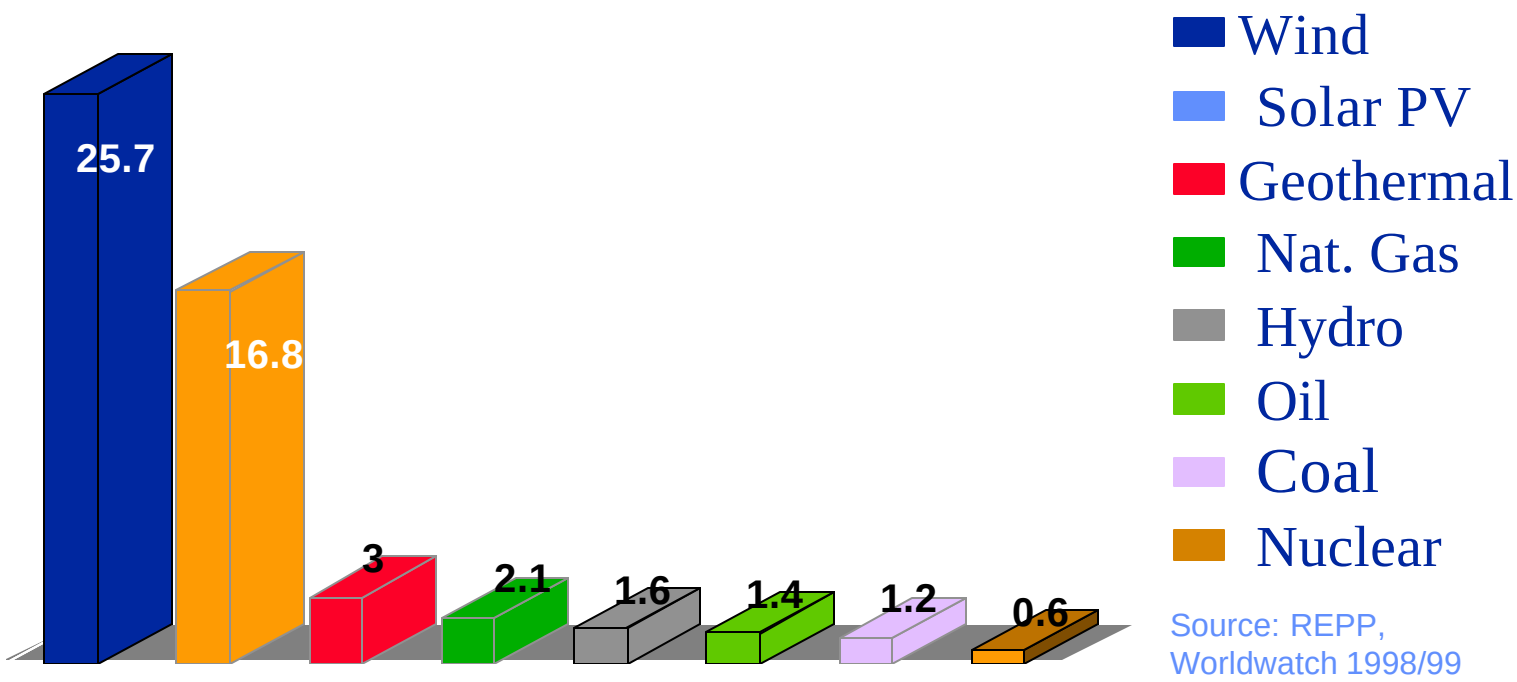
Assumptions: Levelized cost at "excellent" wind sites, large project size, not including PTC (post 1994), costs in nominal cents/kWh.

Wind Energy is the Star of the Green Market

- Environmental Benefit
- Popular
- Visual Appeal
- Hydro and Gas Resources Complementary
- Modular
- Cost-Competitive

Fastest Growing Energy Source in the World

Global Growth by Energy Source, Annual Average, 1990-98



Source: REPP, Worldwatch 1998/99

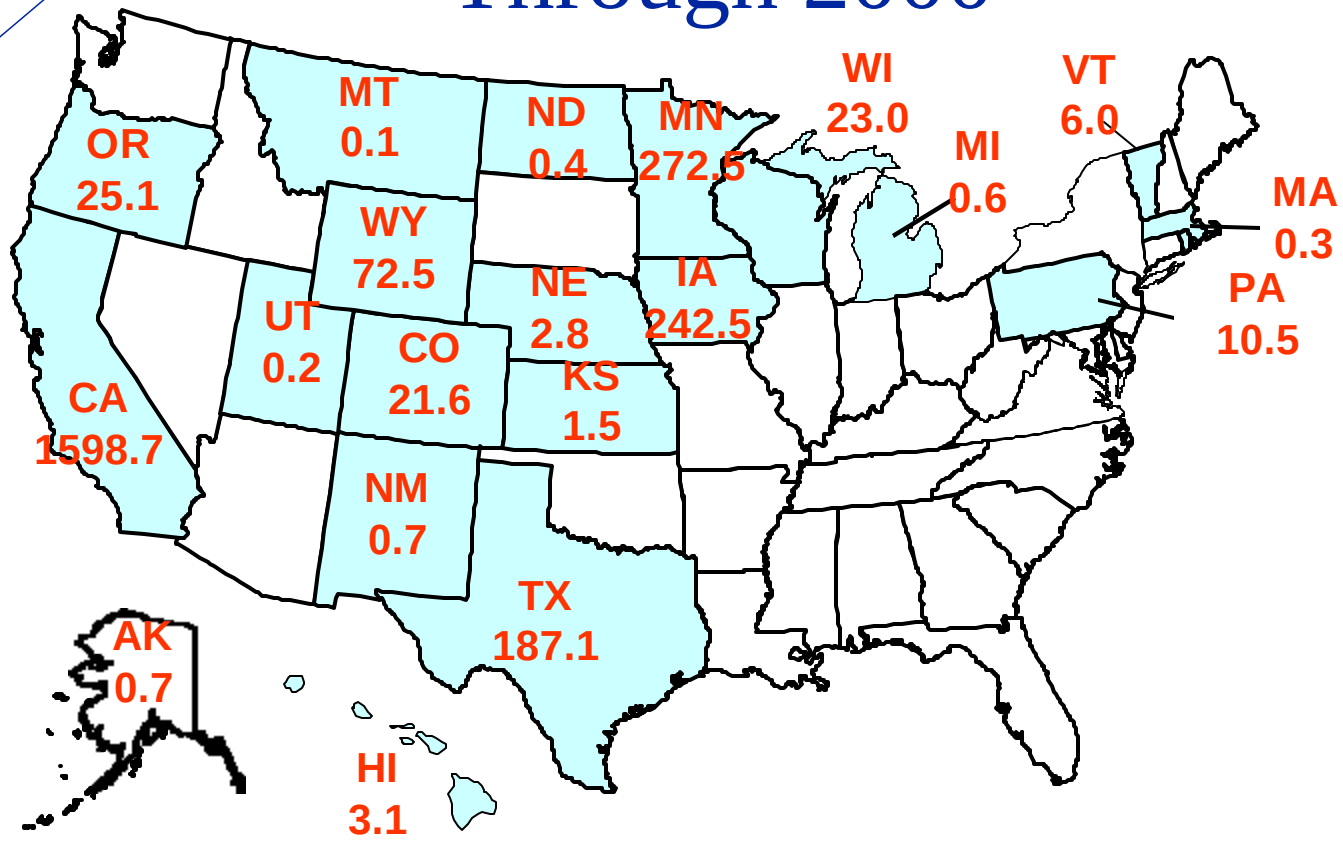
1999: An Outstanding Year for the Wind Industry Worldwide

- Almost 4,000 MW of New Capacity Worldwide
- 15,000 MW Cumulative Now Installed Globally

Wind Energy

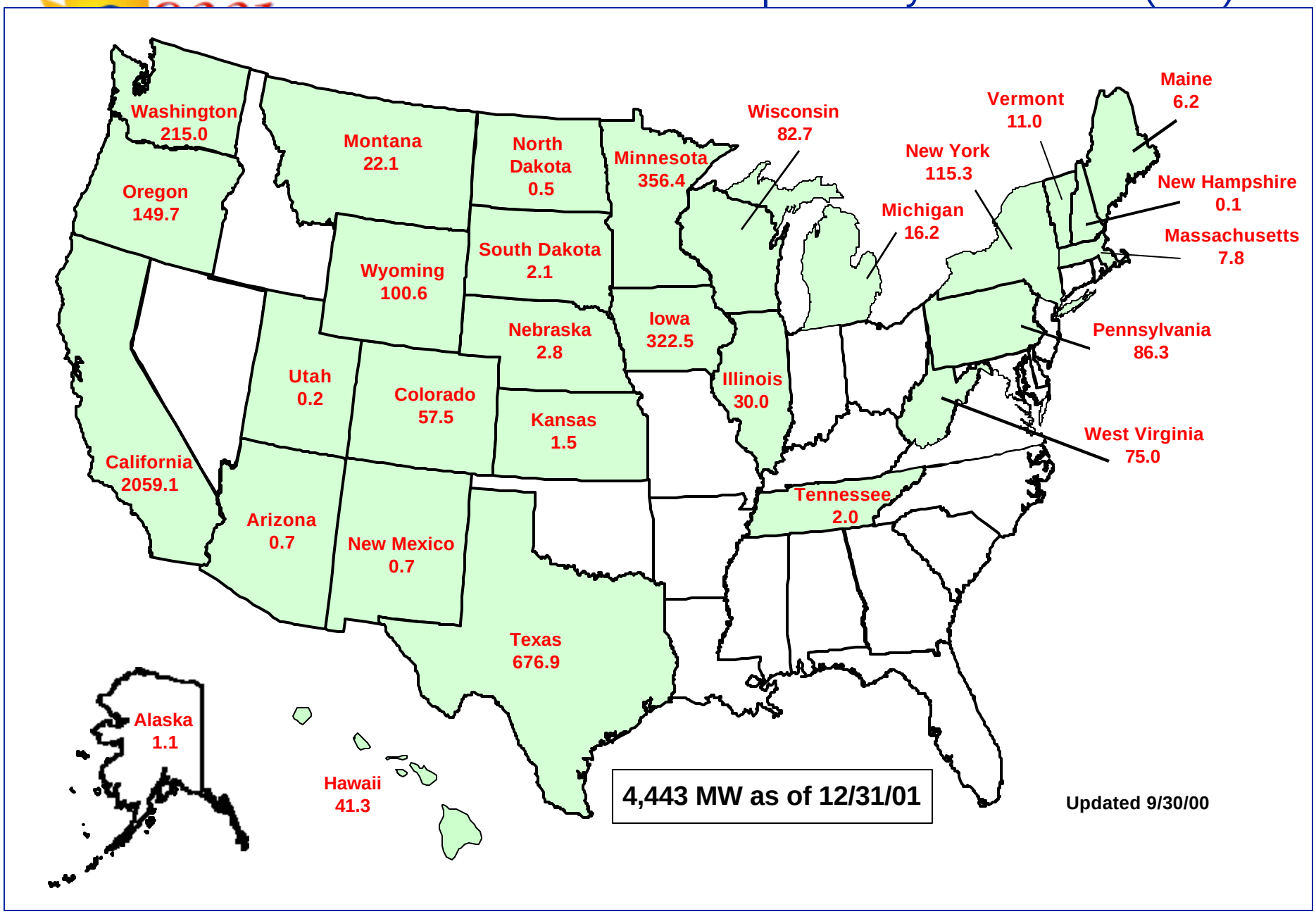
1983

Wind Energy Online Through 2000



2, 470 MW

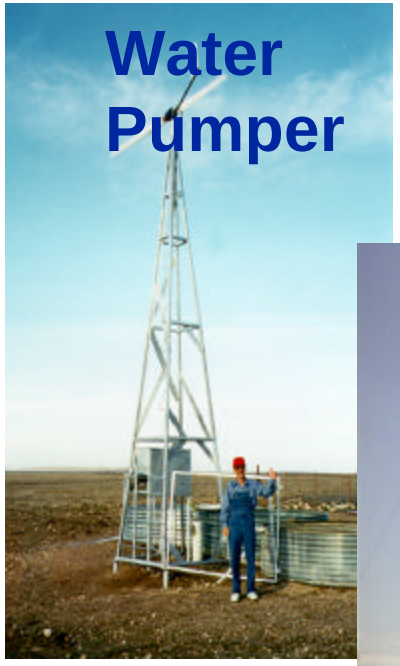
U.S. Wind Power - Expected by end of 2001 (MW)



Driving Forces Behind the Rebirth

- State Policy
- Electric Industry Competition
- Wind's Steadily Improving Economics
- Utility Experience and Perspective

Different Types of Wind Power



Single Large Turbine

Farm

Large and Small are Different

Large Turbines – 100 kW to 1 MW

- Installed in “wind farm” arrays
- Provide power to utility grid
- Require 13 mph average wind sites

Small Turbines – 0.5 to 100 kW

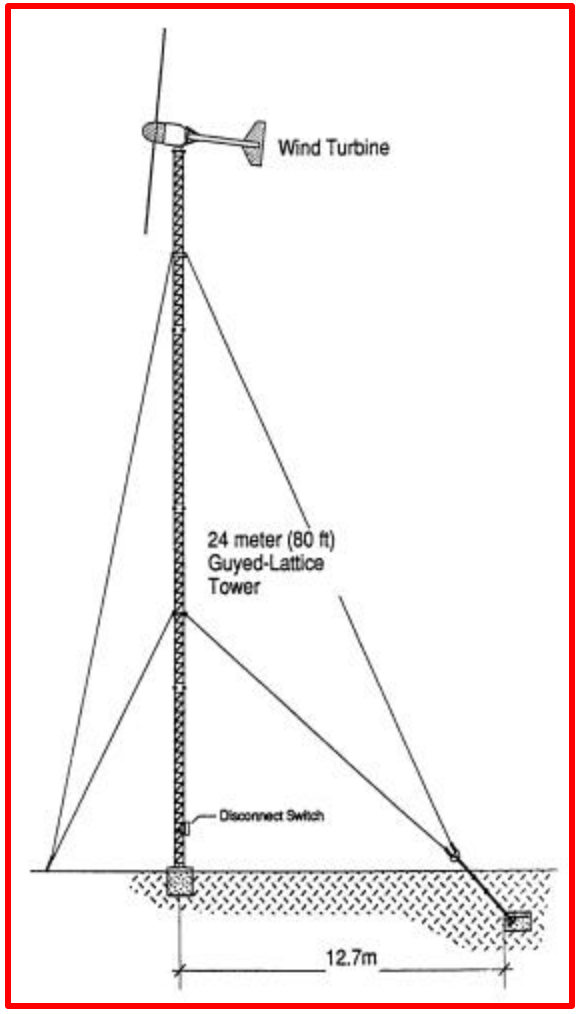
- Installed in off-grid and facility-specific on-grid applications
- Provide power using back-up generation or storage
- Designed for reliability, low maintenance
- Require 9 mph average wind sites

Small Wind Turbines

- Configuration: Up-wind, horizontal axis, 2 or 3 blades, aligned with wind by the tail
- Blades: Fiber-reinforced plastics, custom airfoils, fixed pitch
- Generator: Direct-drive permanent magnet
  alternator, 3-phase AC electrical output
- Overspeed Protection: Passive furling (rotor turns out of the wind), no springs, no brakes
- Result:
  – Simple, rugged design
  – Only 2–4 moving parts
  – Little regular maintenance required

Small Wind Turbine Towers

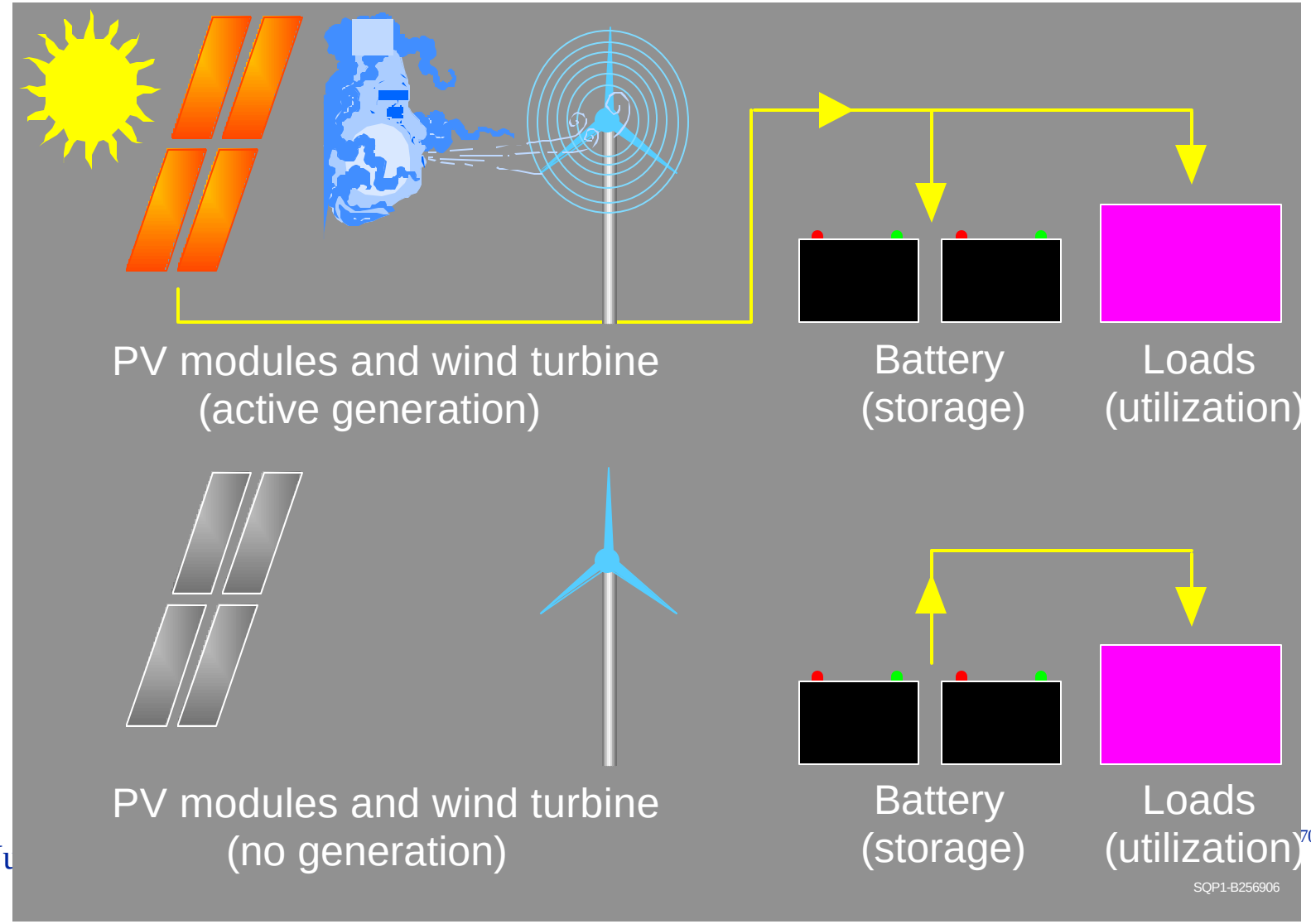
- Guyed lattice and tube towers are the least expensive and most commonly used towers for small wind turbines
- Tilt-up versions are available for easier installation and maintenance
- Adequate space is needed for the guy wires and their anchors
- Free-standing towers are used where space is limited



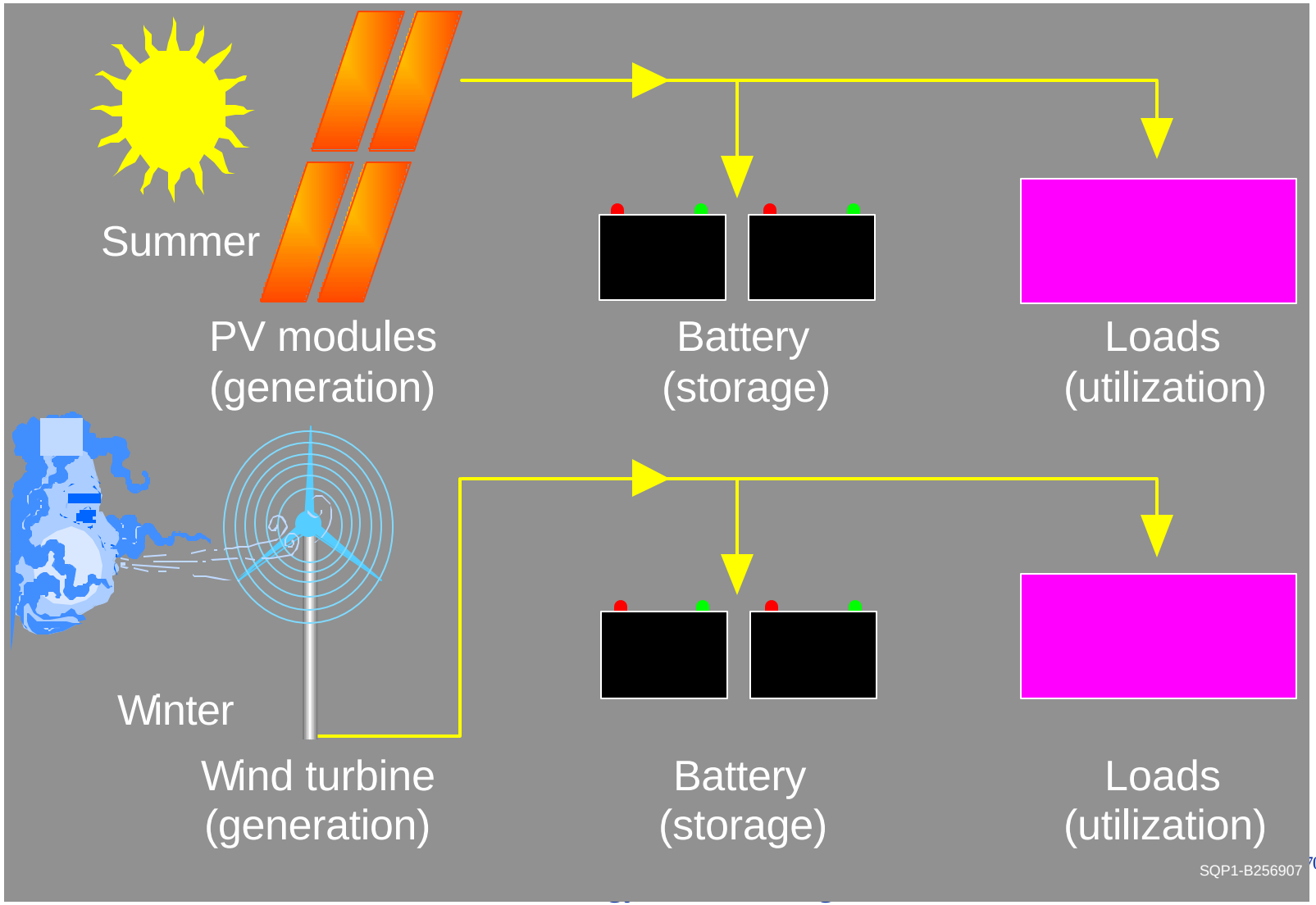
Small Wind Turbines: Maintenance and Lifetime

- Maintenance
  - "Low maintenance" not "no maintenance"
  - Periodic visual inspections
  - Annual maintenance: checking / tightening bolts and electrical connections, replacing leading edge tape as needed, inspecting slip rings
  - Beyond 10 years, replacement of blades or bearings is sometimes needed
- Lifetime
  - Up to 20 years are possible with proper installation and maintenance

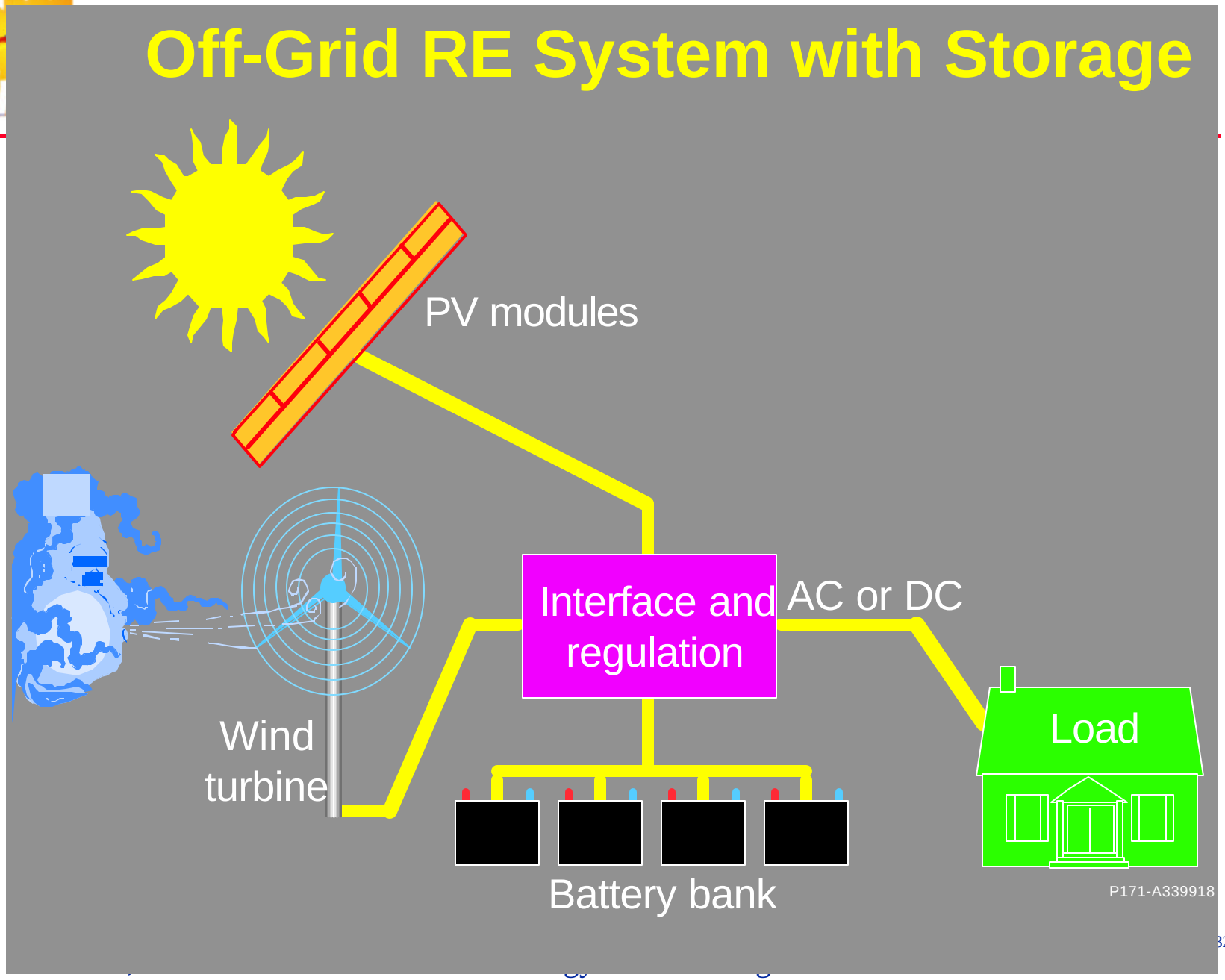
How an Off-Grid RE System Works



The Effect of Seasons on RE Systems



Off-Grid RE System with Storage



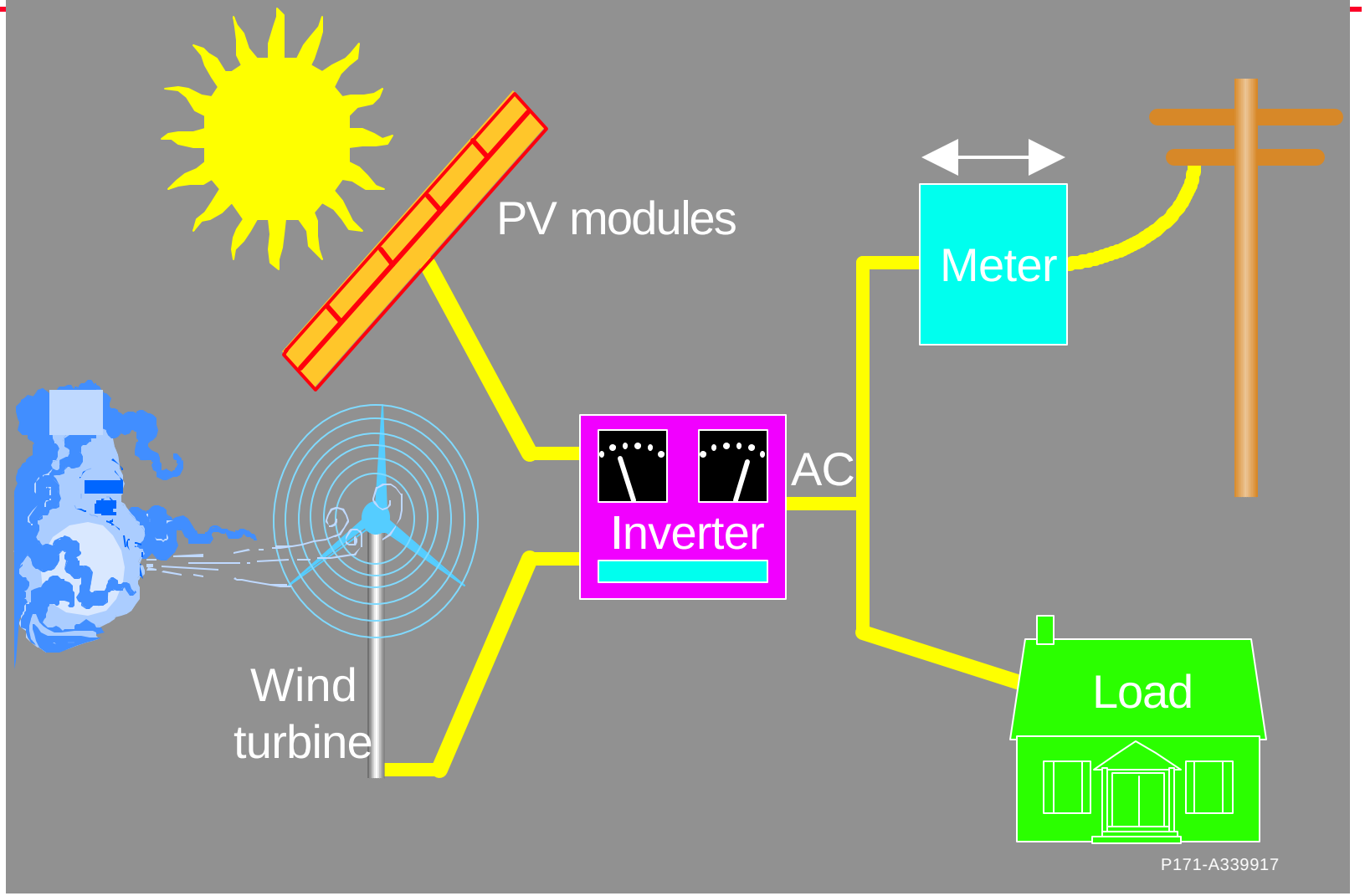
Case Study: Off-Grid Cabin with Wind/PV System

- South Park, Colorado at elevation 9660 ft
- Off-grid cabin occupied 2–3 weekends / month
- Southwest Windpower 503 wind turbine, 500 W, 5 ft rotor, battery-charging, 32 ft tower
- PV panels, 188 W
- 24 V DC battery bank
- Heart inverter, 2.5 kW, delivering 120 V AC, 1 phase
- Installed 1986–1992, total installed cost ~$7500, partly owner-installed
- Space heat from wood and propane
- Hot water, range, and refrigerator use propane

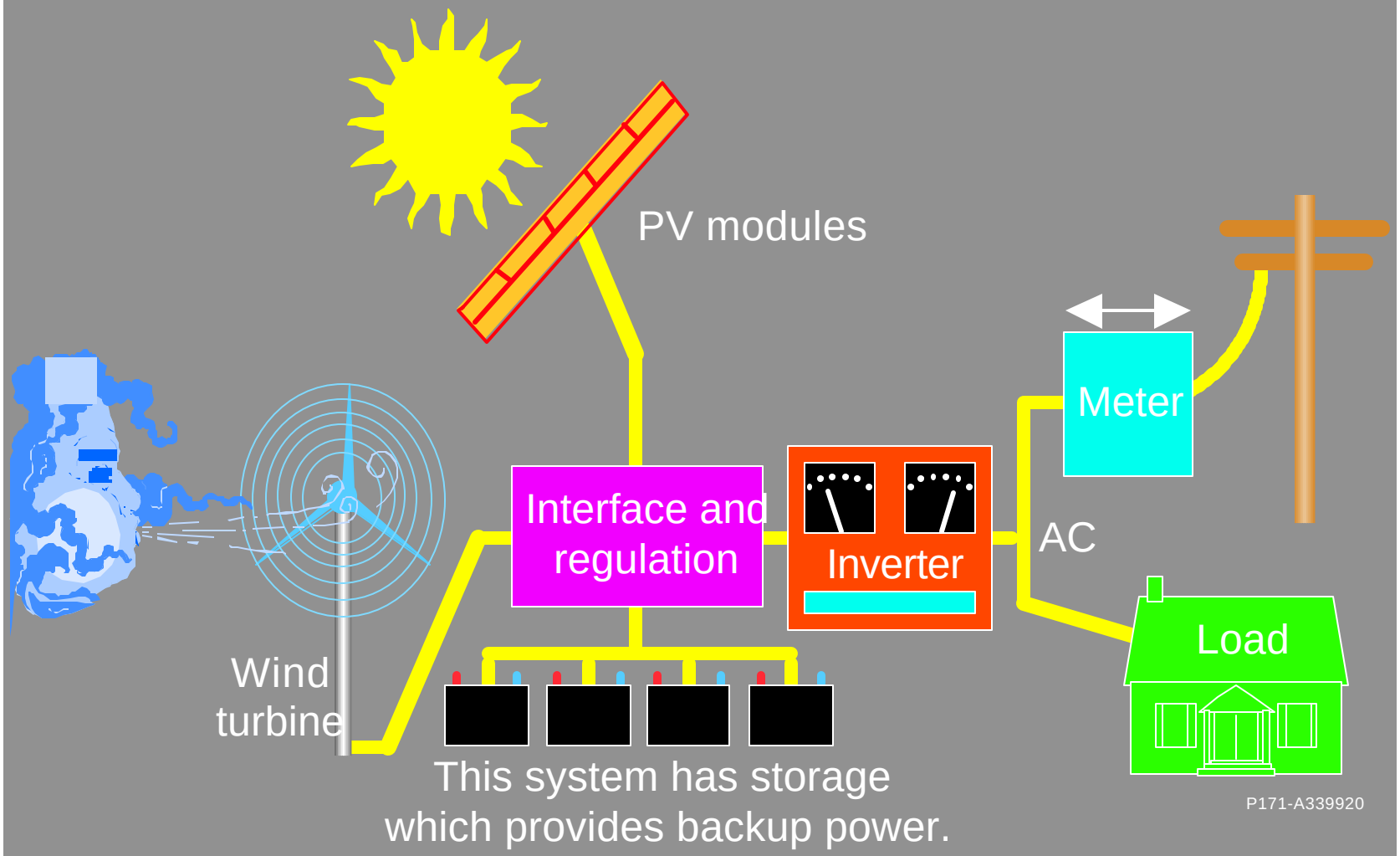
Case Study:
Off-Grid Home with Wind/PV System

- Solectrogen House in Nicasio, California. The house has wind, PV, and solar hot water systems
- House incorporates many energy conservation features like energy-efficient lighting and refrigeration
- Prices range from $20,000 to $40,000 depending on the PV system size

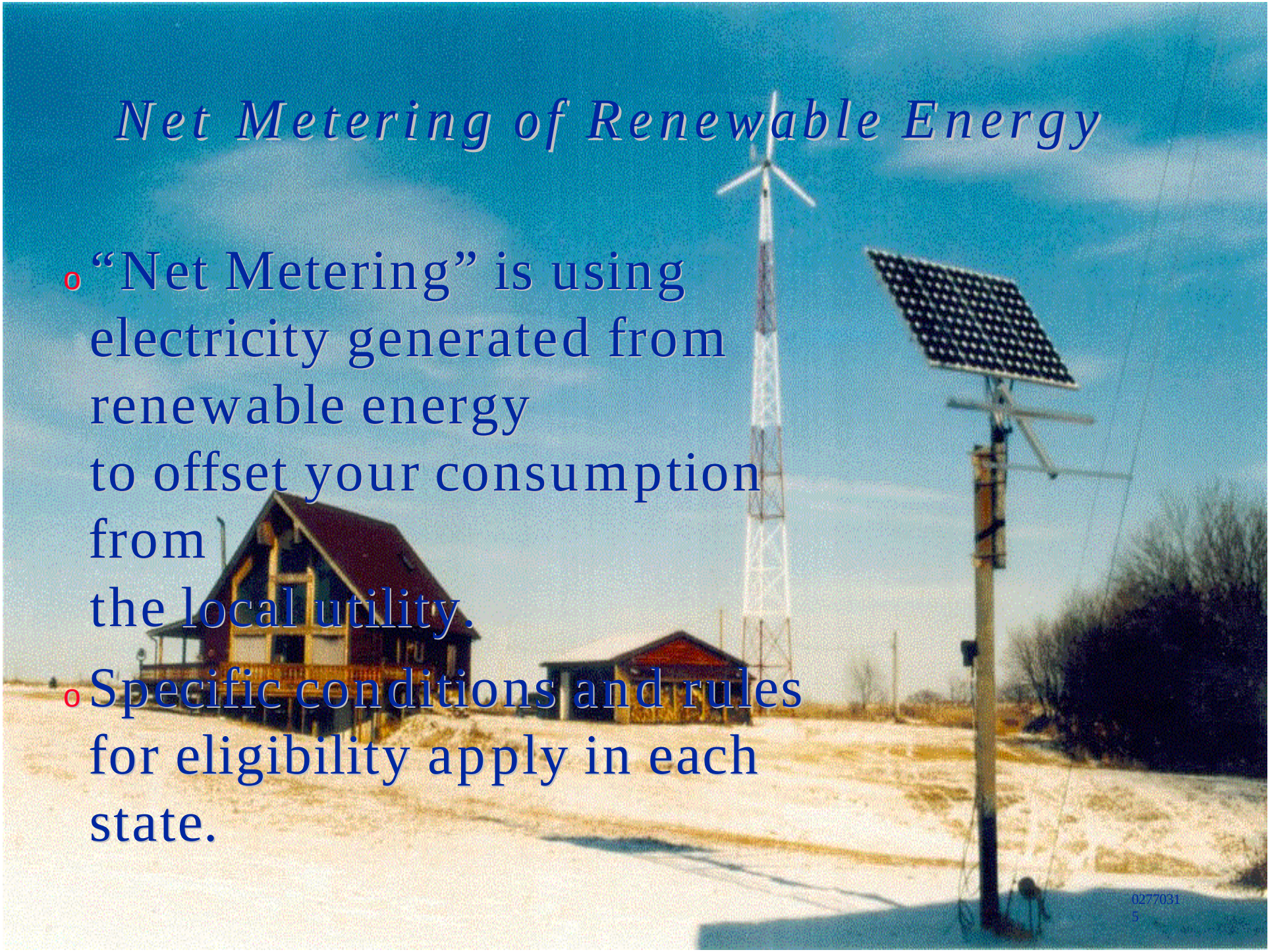
On-Grid AC System without Storag



On-Grid AC System with Storage



Net Metering of Renewable Energy



- "Net Metering" is using electricity generated from renewable energy to offset your consumption from the local utility.
- Specific conditions and rules for eligibility apply in each state.

Case Study: On-Grid Home with Wind/PV System

- Rural Boulder County, Colorado, net metering for utility bill reduction
- World Power Technology Whisper 3000 wind turbine, 3 kW, 14.8 ft rotor, battery-charging, 23 ft tower
- BP Solar model 590 PV panels, 8.6 kW
- 54 V DC battery bank
- Pair of Trace SW5548 inverters, 240 V AC, 1 phase, 11 kW total
- Total installed cost ~$100,000
- All electric home including heat pump and electric car
- Passive-solar,super-insulated home design

Case Study: On-Grid Farm with Wind System

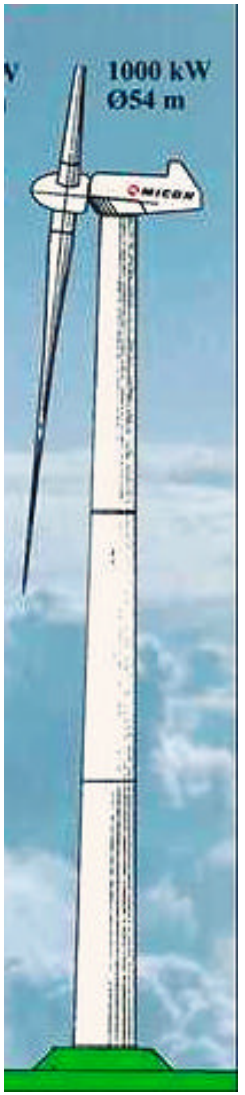
- Clover Valley, Minnesota
- Utility bill reduction
- World Power Technology Whisper 3000 wind turbine, 3.0 kW, 14.8 ft rotor, 50 ft tower

Case Study: On-Grid Small Business with Wind System

- R&M Mechanical Systems, Norman, Oklahoma
- Net metering for utility bill reduction
- Bergey Windpower Excel wind turbine, 10 kW, 21 ft rotor, 80 ft tower
- Installed in 1984
- $22,000 total installed cost
- Owner received an $8000 tax credit and was allowed 5-year depreciation
- ~15,000 kWh / year generation, utility bill savings are ~$1300 / year
- Maintenance and repair costs ~$75 / year

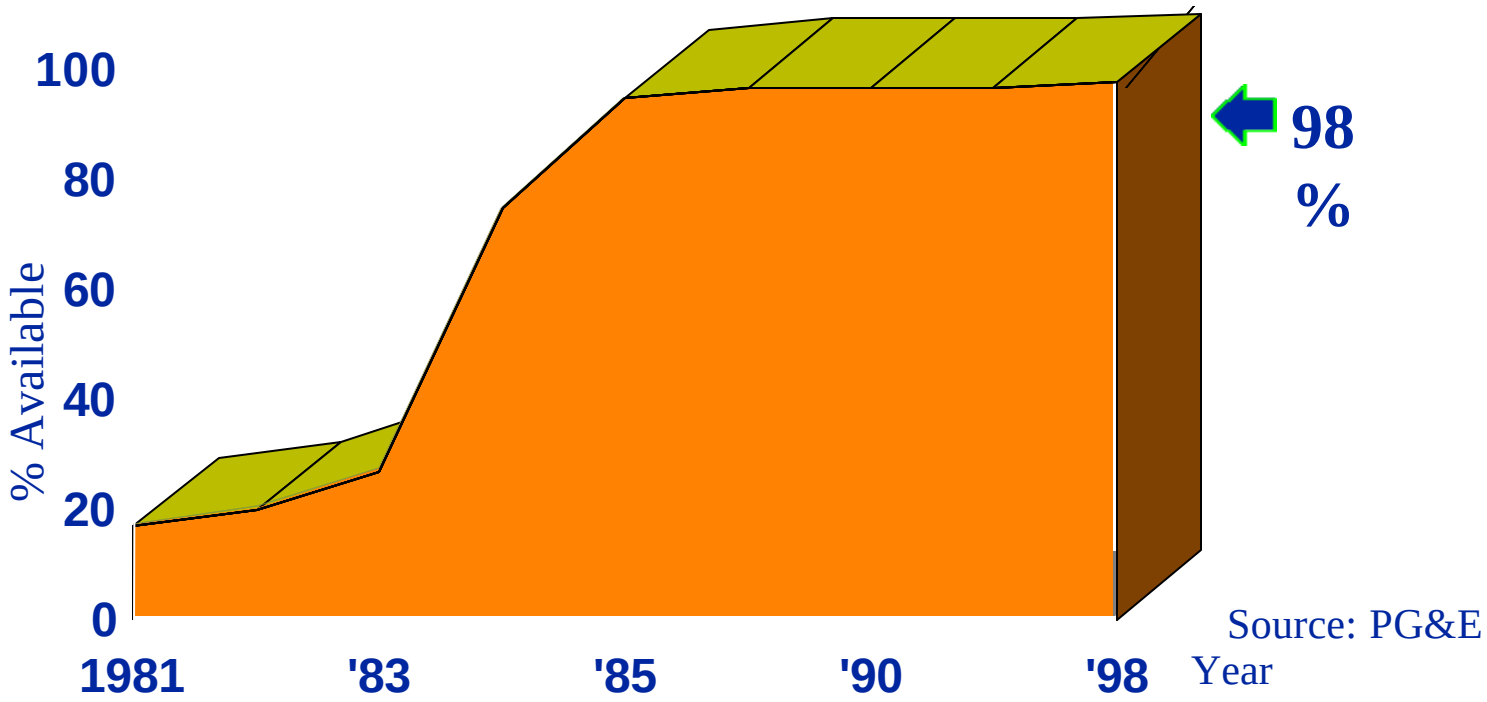
Economies of Scale Drive Down Cost

	1981	1998
Rated Capacity	25kW	750kW
Rotor Diameter	10 meters	50 meters
Total Cost ($000)	$65	$600
Cost Per kW	$2,600	$800
Output, MWh/year	45	2,500



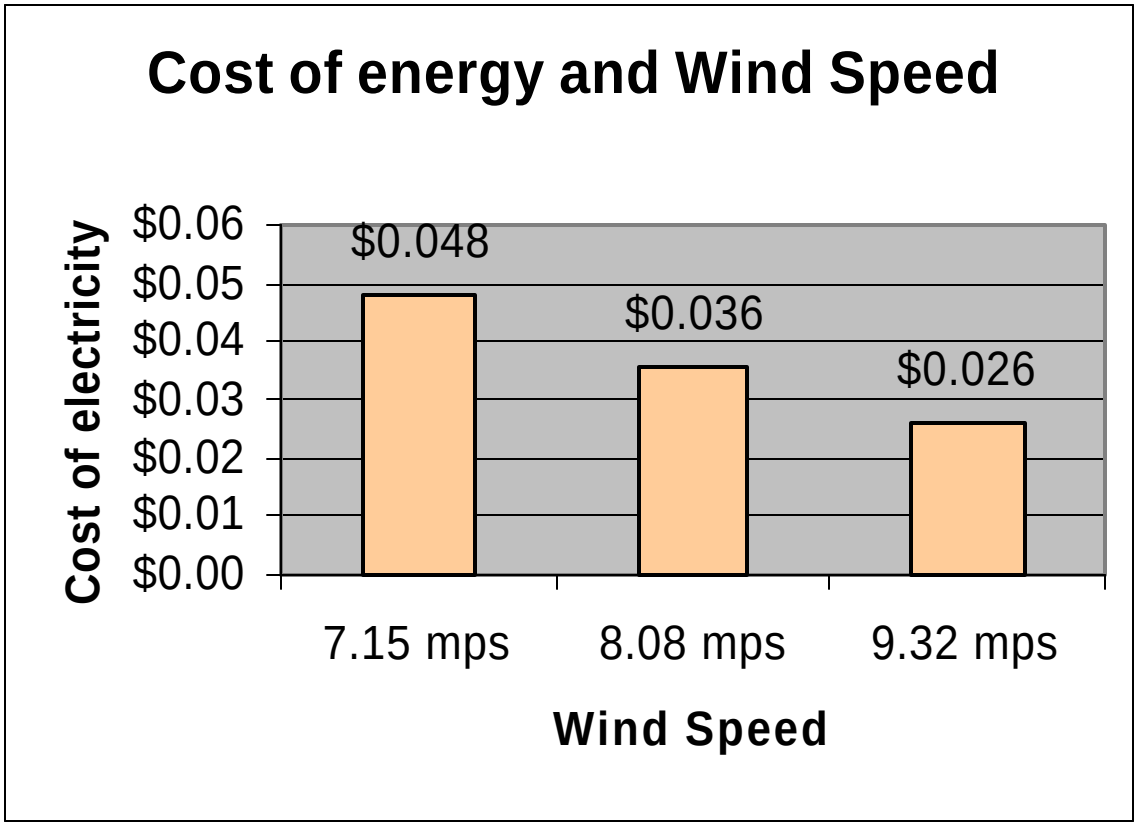
56 x the energy at
9 x the cost!

Availability of Better Wind Technology



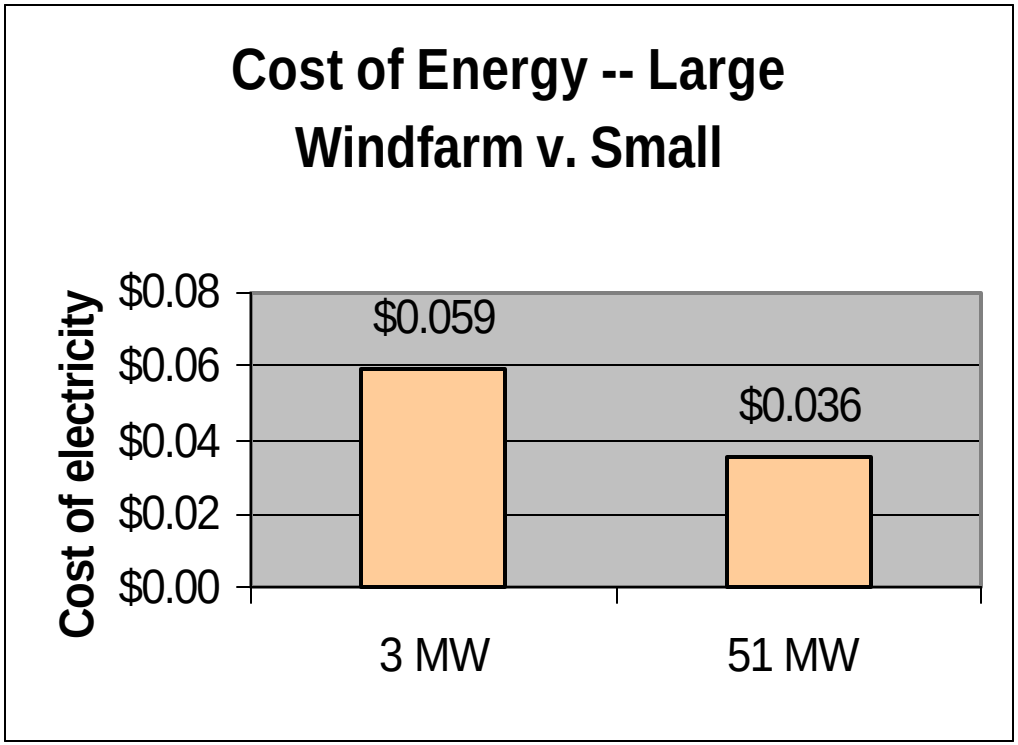
Average Percent of Turbines Available for Operation at Any Given Time

Acquiring Wind Least-Cost: Wind Speed Matters



Assuming the same size project, the **better** the wind resource, the **lower** the cost

Acquiring Wind Least-Cost: Project Size Matters



Assuming the same wind speed of 8.08 M/S, a large wind farm is more economical

Growing Utility Involvement with Wind Energy

- 175 Suppliers now offer a Wind-based Green Product in 25 States
- Planned in at least 4 more

Future Trends or Driving Forces in the Electric Industry

- Increasingly Competitive Electric Industry
- Increasingly Stringent Environmental Controls
- Continued Movement Toward Distributed Generation
- Growing Appreciation of Generation Portfolio Diversity

Wind - Natural Gas Compatibility

Wind		Natural Gas
Low Operating Cost	→	High Operating Costs
High Capital Cost	→	Low Capital Cost
Non-dispatchable	→	Dispatchable
No Fuel Supply / Cost Risk	→	Fuel Supply / Cost Risk
No Emissions	→	Smog, Greenhouse Gas Emissions

Market Barriers

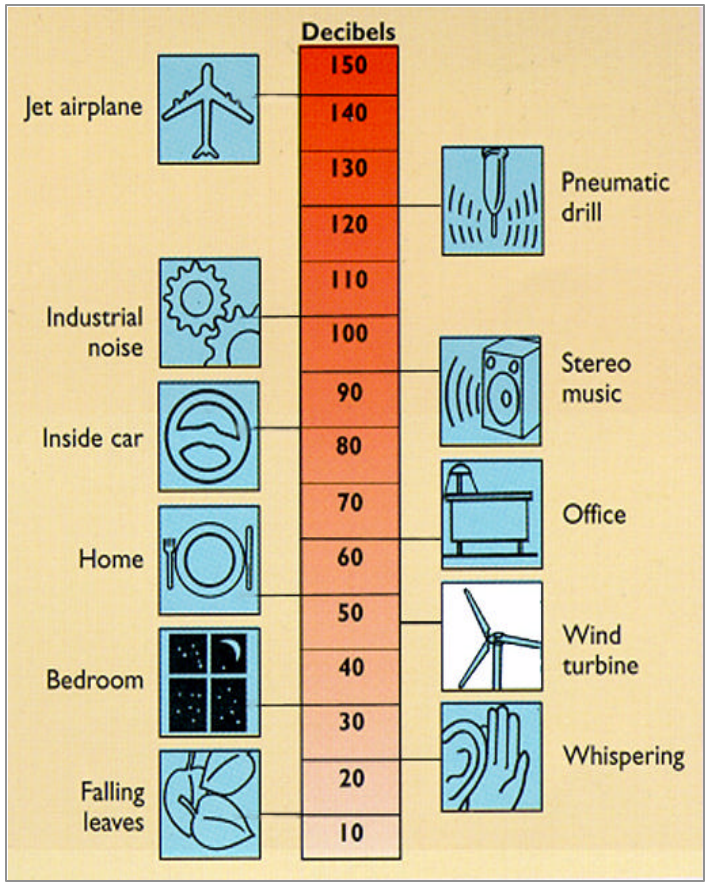
- Siting Issues
  - Avian
  - Noise
  - Aesthetics
- Transmission
- Intermittence

Market Barriers

Is Noise an Issue?

How Much Noise Do
Wind Turbines Make?

45 decibels
at 350 meters



Federal Goals for Renewable Energy

Executive Order 13123

- 2.5% of Federal electricity from green sources

Windpowering America

- 5% of Federal electricity from wind by 2010
- 5% of U.S. electricity from wind by 2020

Executive Order 13123

E.O. 13123, Greening of the Government through Efficient Energy Management was signed by President Clinton on June 3, 1999.

Section 204 - "Each agency shall strive to expand the use of renewable energy… by purchasing electricity from renewable energy sources"

Section 404c - "Agencies should include provisions for the purchase of electricity from renewable energy sources as a component of their requests for bids whenever procuring electricity." Agencies may use savings from energy efficiency projects to pay the additional incremental costs of electricity from renewable energy sources"

Wind Powering America

Announced
June 1999

"Wind energy has been the fastest growing source of energy in the world during the past decade and now represents a major economic opportunity for the United States.

Wind Powering America will help us promote regional economic development, increase America's energy security, and protect our environment for generations to come."

Bill Richardson, Secretary of Energy

Goals:

5% of nation's electricity by 2020

Double the states with 20 MW installed to 16 by 2005, and then to 24 by 2010

5% of Federal electricity use by 2010 (1,000 MW)

DOE Green Power Directive

- Secretary Richardson directed DOE to buy green power, April 20, 2000
- 3% of electricity needs from non-hydro renewables by 2005...7.5% by 2010
- In deregulated states, DOE will competitively select suppliers
- No increase in utility bill expected
- First Federal agency to make Department-wide commitment

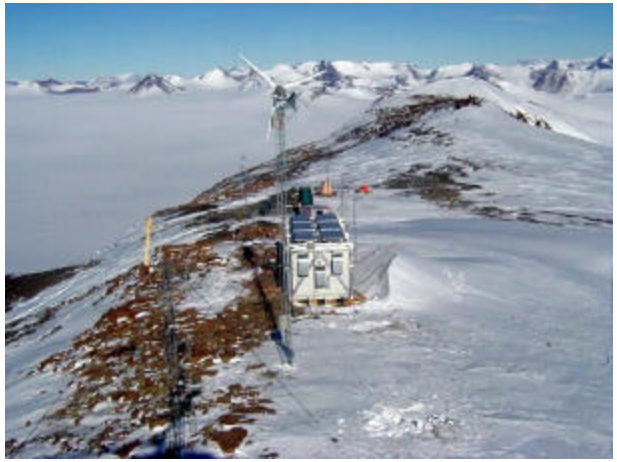
Military is Key

DoD accounts for as much as 85% of the Federal energy use
Without significant participation by the military services,
Federal wind energy goals cannot be met
There is currently no DoD policy encouraging military bases and commanders to participate in green energy purchases

Mechanisms for Federal Wind Energy Purchases

- Direct purchase of wind turbines
  - Capital investment funds for large projects
  - Operating funds for small projects
  - Energy investment funds (e.g. DoD “ECIP”)
- Developer funding
  - Energy Savings Performance Contracts
  - Other innovative contract arrangements (e.g. Ft. Bliss, TX)
- Green energy purchases
- Green “tags”

Existing Federal Wind Projects



San Clemente Island, California

U.S. Navy island 53 miles off San Diego
Diesel powered grid
Average demand 850-950 kW
Wind provides 14% of electricity annually

Ascension Island

U.S. Air Force installation on British island in mid-Atlantic ocean.

Prime diesel generation with rotary interconnect to British 50 hertz system

Up to 10 added turbines planned

Camp Williams, UT (Utah National Guard)

One NEG Micon 225 kW turbine purchased through FEMP
Other funding from U.S. National Guard Bureau, Utah state energy office, and Utah National Guard
Installed March-May 2000
At least one additional turbine planned

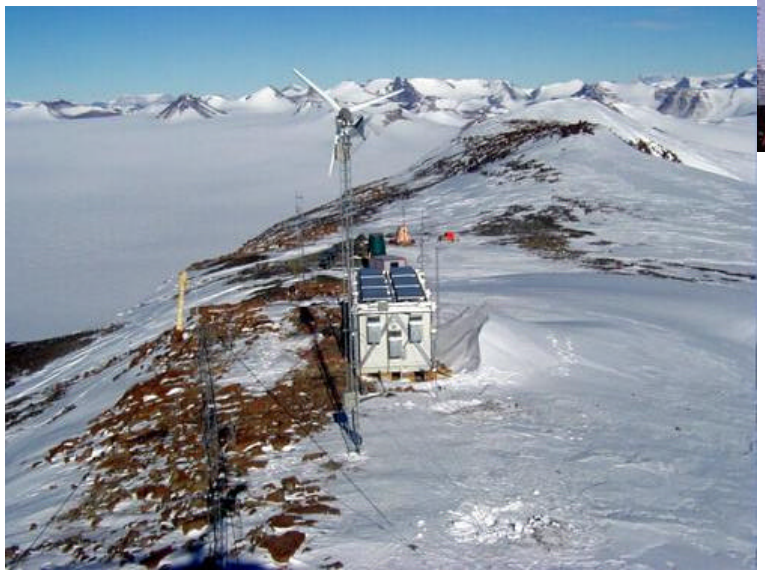
Planned On-site Projects

- Navy planning additional turbines on SCI; considering turbines for San Nicholas Island, CA and Wallops Is., VA
- Air Force planning up to 10 added turbines for Ascension Island; considering Vandenberg AFB, CA
- Army considering Ft. Bliss, TX; White Sands Missile Range, NM; Ft. Huachuca, AZ

National Science Foundation, Antarctica

Two remote communications relay sites
Unmanned
Operated year round
Wind, PV, propane hybrids

Black Island



Mt. Newell

FAA Chandalar Lake, AK

- FAA aircraft navigation beacon at Chandalar Lake in Brooks Range, northeast AK.
- Accessible only by air.
- Previously powered by diesel generators--fuel flown in.
- Decided on an all-renewables system in 1999.
- Two Bergey 7.5 kW turbines on 30 m (100 ft) guyed-lattice towers, 5 kW solar array, 48 VDC sealed battery bank, switchgear, and two Trace sine wave inverters.

Green Energy Purchases

Clearly the WPA goal of 5% (1000 MW) of Federal wind energy by 2010 will not be met through Federal purchase of wind turbines

Several sizable Federal green energy purchases have already been announced

Significant opportunities exist for large Federal purchases of green energy and “green tags”

Mechanisms for Federal Wind Energy Purchases

- Direct purchase of wind turbines
  - Capital investment funds for large projects
  - Operating funds for small projects
  - Energy investment funds (e.g. DoD “ECIP”)
- Developer funding
  - Energy Savings Performance Contracts
  - Other innovative contract arrangements (e.g. Ft. Bliss, TX)
- Green energy purchases
- Green “tags”

Colorado Federal Wind Purchase Initiative

- Led by Denver Federal Executive Board (DFEB)
  - DFEB represents over 130 federal agencies in metro area.
  - Worked in partnership with GSA, DOE Denver Regional Office, DOE Golden Field Office, NREL and EPA.
- Goal - 10 MW wind purchase by federal facilities in Colorado through utility green pricing programs.
- Request federal agencies to commit to purchase equivalent to 10-25% of load in order to meet 10 MW goal.

Leadership Opportunities

- Demonstrate leadership in complying with renewable energy and greenhouse gas emission reduction provisions in federal Executive Order 13123
- Demonstrate federal commitment to the community
- Demonstrate environmental commitment - help meet air quality and health goals
- Demonstrate good stewardship
- Strengthen employee morale

Challenges to Federal Wind Energy Purchases

Most Federal agencies are operating with fixed or declining budgets, especially for energy purchases.

Despite the provisions of E.O. 13123 allowing expenditure of energy savings, most savings are owed to ESCO's or have been pledged to other programs or removed from the agencies' budgets

Results

- Our success-- 31 commitments (10 MW)

- The largest agency commitments
  --Ft. Carson Army - 4661 blocks
  --DOE Rocky Flats - 3000 blocks
  --DOI -USGS - 2000 blocks
  --EPA - 1670 blocks (100%)
  --NREL - 1651 blocks
  --VA Medical Center- 1443 blocks
  --US Mint - 1000 blocks

Recognition Ceremony and Press Conference

April 27, 2000

Denver, Colorado

Participating Agencies with the Department of Energy Secretary Bill Richardson and group of children

Work Remaining

Increase the Denver commitment from 3% to 5-10%

Provide assistance in finding energy savings to offset cost of Wind Source

Turn informal commitments into signed contracts with utilities

Aggregated DOE purchase

- 3% of DOE electricity
- Equivalent to 60 MW of new wind capacity

Other Federal purchases

Web Sites

- **FEMP Web Site -** www.eren.doe.gov/femp/
- **EO 13123 -** www.eren.doe.gov/femp/aboutfemp/exec13123.html
- **GSA Green Power -**www.gsa.gov/pbs/centers/energy/green.htm
- **Wind Powering America -** www.eren.doe.gov/windpoweringamerica/
- **GeoPowering the West -** www.eren.doe.gov/geopoweringthewest/
- **GSA Request for Proposals -** www.gsa.gov/pbs/xu/co1.htm
- **DOD Request for Proposals -**
  www.desc.dla.mil/main/a/electric/index.htm
- **Green Power Network -**www.eren.doe.gov/greenpower/home.shtml

  1) Green Pricing Programs - www.eren.doe.gov/greenpower/pricing.shtml

  2) Competitive Green Power Products
  www.eren.doe.gov/greenpower/marketing.shtml